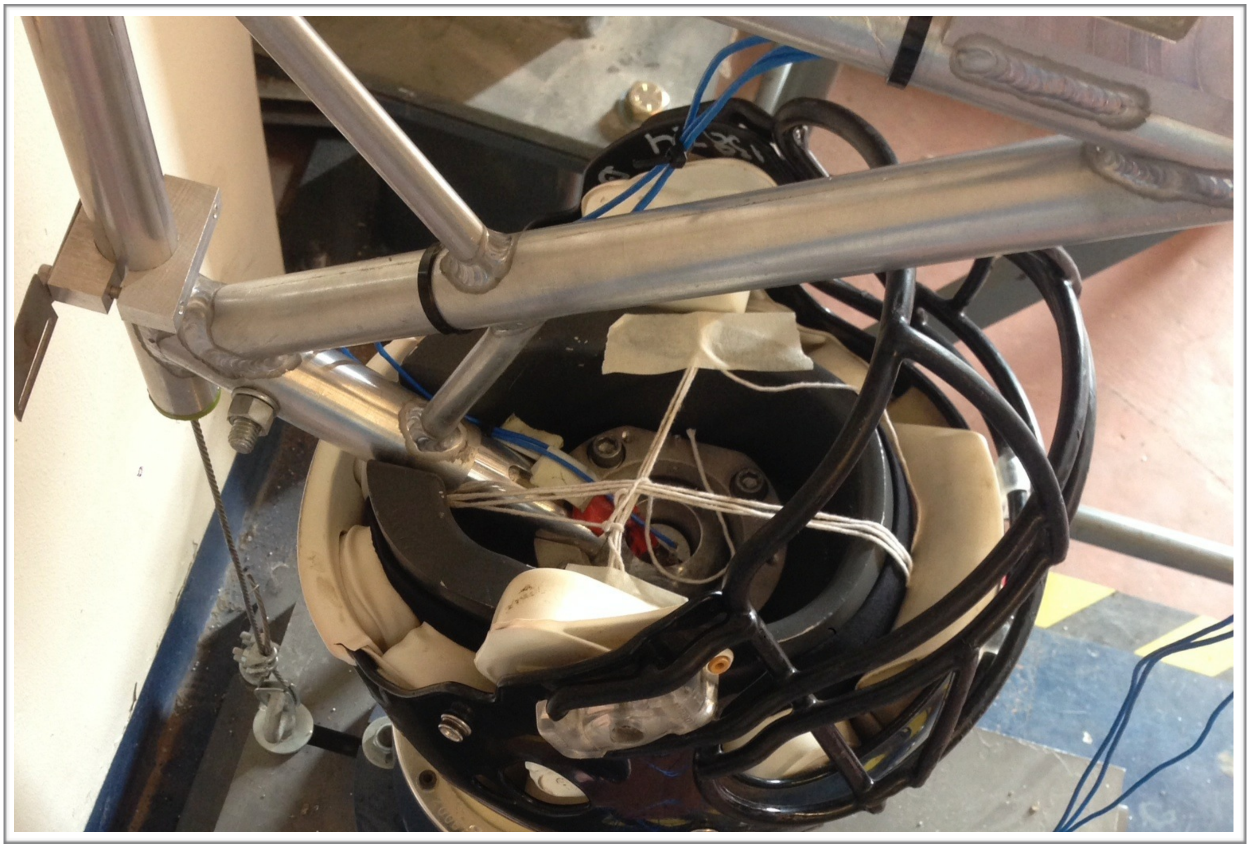
Impact Testing of Youth-Level Helmets Versus College-Level Helmets



Nicole Hermann

Cal Poly Industrial Technology

Orfalea College of Business

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Abstract

With so many studies being conducted on professional football players regarding concussions and other related brain injuries, it's amazing that such an important demographic has been missed. While NFL players are just as subjected to serious injuries as anyone else or even more so, it is important to remember that these players are outfitted, in most cases, with top-of-the-line equipment -- especially their helmets. If the focus is shifted to a younger demographic, youth football players in middle school and high school, the equipment is far less advanced and in a vast majority of cases, has been previously used by a number of other players. This is no exception when it comes to the one piece of equipment that arguably protects the most important part of the human body: the brain.

Football helmets in the NFL already get a great amount of attention when it comes to their effectiveness of protecting a grown man's head. For youth players with still-developing brains, however, helmets are an even greater necessity. This is especially true when public schools are facing budget cuts and can no longer afford to replace helmets after they have been used. In some cases, schools are requiring parents to provide their own helmets for their children. If the family is wealthy enough to afford a safe and proper helmet, this is not a problem. Unfortunately, it is no surprise that many families cannot afford a helmet that protects their child's head as much as it needs to be. The lack of proper equipment increases the chances of concussion and, later in life, increases the chance of brain diseases, such as Chronic Traumatic Encephalopathy (CTE). CTE has serious consequences and has even been studied as a factor in suicides in former college and professional football players.

A less expensive, and usually effective, alternative to helmet replacement year after year, is reconditioning. This can be anywhere to one-sixth to one-third of the price of helmet replacement. In many cases, reconditioning can even be as good as replacing the helmet for players that are not impacted as often such as kickers and receivers. Riddell, a prominent and major brand in football helmets, explicitly recommends that helmets should be *replaced* at least every three seasons at the youth level. More importantly, there are also laws put in place by the National Operating Committee on Standards for Athletic Equipment (NOCSAE) regarding the reconditioning and refurbishing time-lines.

This study has the purpose of reaching all grade schools across America. A large number of schools have tight budgets and student athletes are not always at the top of the budgeting list. All too often, this is leading to improper safety equipment maintenance, which is something that cannot be taken lightly. As mentioned, concussions are the most common injury when high impact levels are considered in football, and these concussions are a very small symptom of a disease that could develop if proper precautions in safety are not taken from day one.

By performing the same helmet impact testing on both college-level (which are reconditioned annually) and youth-level helmets, it is expected to prove that youth helmets are not as safe as adult helmets and that youth helmets need to be reconditioned or replaced more often as college level helmets are. It is important to note, for the purposes of this study, that both levels of helmets have materials and safety specifications on par with each other due to the need to comply with certain industry standards.

Acknowledgements

Without the help of many people, this study would not have been possible. The support and admiration of a project having to do with the safety of the youth football players of America was overwhelming. From student help, professor advice, and professional athlete guidance, this project has ended up being a thorough look into youth safety in football.

Thank you to Professor Jay Singh for guiding and advising the study from start to finish. There were plenty bumps in the road, but in the end the testing and analysis was completed and turned out to prove the hypothesis correct. With the help of Professor Jay Singh, one of Cal Poly's finest package engineering and technology professors, the information in this report could change the outlook on football head protection for children.

Christopher and Tom Fuhrman, were also a significant help during the planning, testing, and discovery phases. Christopher is the inventor behind an effort to fabricate a protective skull cap and an avid supporter of the cause behind this study. During their visit to the the Cal Poly testing facility, they helped in testing helmets and were a major inspiration to the project.

Sally Yingst, a first year transfer student from UC San Diego, generously joined the project midway through to assist the actual testing of the helmets. Ample drops and many hours spent in the dynamics laboratory were absolutely necessary to compile data and information needed to complete the project; and Sally has proven herself to be one of the most valuable assests to the study. Prior to her years at UC San Diego, she is a transfer student and has only been at Cal Poly for one year, she has proven herself as one of the most valuable people of the study in its entirety.

Professor Soma Roy who teaches statistics courses at Cal Poly was always available to lend a hand in the analysis of the raw data collected. Her professional opinions and advice always helped steer the project in the direction it needed to go in order to get the best results.

The Cal Poly equipment manager, Steve Kracher, was more than generous in providing not only testing subjects, but in offering good advice. He is very knowledgeable about the sport as well as the equipment needed to play safely. He was a major component when it came time to look at the current process for college football equipment reconditioning and replacement. The information he gave was used as a model for reconstructing the youth football helmet reconditioning and replacement process.

Last but not least, appreciation of Sullivan Grosz's study on blunt impact of football helmets in relation to pad pressure was a huge help for this study. Not only was the report helpful, but Sullivan was always willing to contribute to the project and help in anyway needed.

Table of Contents

List of Figures

List of Tables

List of Images

Introduction

Problem Statement

Football is easily one of the most loved and watched sports in America. The sport is even growing in popularity in other countries around the globe. However, with all of this media attention directed towards the NFL, college and arena football teams and players, it is easy to overlook what comes before these professional leagues. Many of the most famous football players started playing as children in middle school and high school. Underneath all of the glamour, football is also recognized as one of the most dangerous sports in terms of the amount of injuries, and especially the amount of head injuries. These include both subdural hematomas and Chronic Traumatic Encephalopathy, which can eventually lead to suicidal tendencies.

CTE develops from having many concussions and usually only appears many years after a player's career in high-contact sports. Similarly, subdural hematomas are also common in football players, resulting from multiple collisions and concussions. This is why the youth football demographic needs to be considered much more than it seems to be today. The earlier the head and brain can be protected, the better the player's chance of a long and healthy life (free of CTE or any other brain disease). Thus, this study will look at the current safety of children's football helmets (4th-12th grade) and compare this safety to college level helmets that are reconditioned annually and replaced an average of every five years.

Needs

Scientists generally agree that around the age of 25 years old, the human brain becomes fully developed. Before this time, the brain is perpetually learning, whether it is how to talk, how to walk, how to deal with other people in the world, or simply learning in math class. During these years of development, it is especially important and necessary to protect the brain as it grows. Most NFL players are towards the end of this development period or completely out of it and they already experience hundreds of impacts each season. Middle school and high schoolers, on the other hand, are fully immersed in learning and developing and can also experience a number of impacts near the number NFL players experience, depending on field position.

Children need their heads protected and cannot take the risk of wearing used helmets that offer inadequate support and safety from impacts. Children innocently take their safety for granted and don't often think of the implications of rough play, even though their helmets are far from safe. Youth football players should be able to take their safety for granted because their equipment *should* already be safe.

Background or Related Work

There have been many studies conducted on the safety of football helmets and the injuries that result from playing the sport. Most recently, there was a study from Cal Poly University done by Sullivan Grosz (the school's football captain at the time) that looked at the relationship between the pressure in the football helmet's pads versus how much shock a player's head receives. He used Riddell Revolution helmets for his study, which is what the players at the college wear during their games. I assisted Grosz with his study and that experience led me to an interest in doing my own study. After participating in Grosz's research, I used the knowledge and experience I gained to shift the focus to the youth demographic and the standards used for reconditioning or replacing the helmets.

The original idea for observing youth football helmets, came from Christopher Fuhrman's idea to design and manufacture a bladder to be placed in a skull cap that can be worn under a football helmet. This idea came from the desire to find an inexpensive way for grade schools to provide better protection for their student athletes. Fuhrman is a former football player who was the victim of serious injury that came from head trauma during a high school football game. Following is his story and an example of just one out of many tragedies that come from youth football injuries.

"To summarize my story, I suffered a subdural hematoma (blood vessel broke in my brain) during a football game my junior year of high school and was nearly pronounced dead on the sidelines. The subdural hematoma was a result of a concussion from the week prior. I didn't say anything to my parents or coaches about the concussion because I wanted to play the next

week. The game that accident happened was the first time the doctor brought oxygen, without it, I would have been completely brain dead. Also, I was able to get to him before I lost consciousness. The doctor recognized the symptoms and immediately applied oxygen. I was [then] life-flighted to the closest major hospital and underwent a six hour brain surgery. I was given a one percent chance of survival, and odds of approximately one in three thousand for living without severe brain damage. When I asked the doctor's assistant if I'd be ready to play by next Friday, he replied, "You'll never play sports again."

I was told that I would spend the next two months in the hospital rehabilitating my body, that was accomplished in only two weeks. My two weeks in the hospital were devoted to learning how to walk, talk, read and write. My brain had sucked all the nutrients and muscle out of my body, leaving me twenty-five pounds lighter in two days. I was awake for about three to five hours during the day. The few hours I was awake were consumed by tests in everything from reading to walking. The tests revealed that I read at 2nd grade level. I knew what I had been able to do before my injury; and every day in the hospital, more tests reminded of what I couldn't do now.

Most injuries like this happen on the field or during practice when a player passes out and by the time a doctor can respond it is too late. It has been thirteen years since the accident and I haven't met anyone who has survived this kind of injury.

After coaching youth football and talking to former football players, I have realized that 1, youth helmets 4th grade – 12th grade do not fit properly, 2, most are old and not reconditioned and 3, the majority of football players I have talked to have said that by 12th grade they'd had multiple concussions" (Christopher Fuhrman).

Objectives

This study will include a total of 15 football helmets broken down into the following categories:

- 6 youth helmets (all Riddell brand)
    - 4 Reconditioned
    - 1 Non-reconditioned
    - 1 Brand new
- 7 college helmets
    - 4 Riddell brand
        - 3 Reconditioned
        - 1 Brand new
    - 3 Schutt brand
        - 3 Reconditioned

Each of the helmets listed above, underwent the same testing. They were dropped on seven different locations around the helmet which are: the front, back, top, front right, front left, right side, and left side.

The objective of this testing is to show that the youth helmets are not as safe as college level helmets; and to increase their safety, they should be reconditioned as often as college level helmets. To quantify this, the helmets will be dropped and a shock value will be given. A lower shock value means a longer time for the player's head to decelerate after being impacted.

Contribute/Target

The specific target of this study is youth football players as a whole. This also targets schools who cannot afford to provide replacements for used football helmets to their student athletes. The goal is to show that if helmets are regularly reconditioned, they can last longer; and more importantly, provide more safety for the child's head. Hopefully, it will be determined that the college helmets, which are tested identically to the youth helmets, will prove to be safer because they are reconditioned after every season. The youth helmets, on the other hand, are expected to test worse because of their irregular and, in some helmets, very outdated reconditioning.

Project Scope

This project will be completed using 15 football helmets in two different demographic categories: youth and adult/college. Helmets will then be divided into groups of reconditioned, non-reconditioned, and brand new. For the test, the helmets will be placed on a headform that is part of a DOT certified vertical impact machine designed especially for helmet testing. These helmets will be dropped seven times each at seven different locations. The helmets will all be dropped at the same locations and will be dropped from the same height every time. The testing machine will also be kept controlled, as the same machine will be used throughout the entire study. During testing, record of the impact in multiples of gravity (Gs) will be kept by hand, as well as by a data collection software on a computer for good measure. The digital data will come from a Saver 9X30 tri-axial accelerometer made by Lansmont. At the end of testing and data collection, statistical analysis will be performed and conclusions will be drawn from these numbers.

Literature Review

“Helmets reduced the risk of traumatic brain injury by just 20 percent compared to not wearing a helmet” (Castillo). After many recent lawsuits and injuries relating to helmets and impacts, in depth research and testing has been done which has come to this conclusion. As a result of these impacts and injuries to the head, and thus the brain, consequences such as CTE (chronic traumatic encephalopathy) could result. One big factor in helmet performance and subsequent injury is the type of impact that occurs. Rotational impacts are much harder for a helmet to protect against. On the other hand, linear impacts showed a huge increase in the helmet’s ability to prevent injury (Castillo). The overall system most widely used to quantify a helmet’s overall safety rating is the STAR system developed by Virginia Tech. The group at Virginia Tech has tested and ranked almost 20 of the most common helmets, including the ever popular models of Riddell helmets.

An uncomfortable subject that has been sweeping sports news is the recent suicide deaths of NFL players due to CTE, or Chronic Traumatic Encephalopathy. CTE develops from having multiple collisions/concussions, with little down time to recover from the impacts. What also must be understood about concussions is that once the first concussion is implemented, it may increase the likelihood of a second concussion by up to threefold (Saffary, Chin and Cantu). Presntly, researchers cannot diagnose current NFL players or anyone for that matter with CTE, rather “ CTE can only be detected and measured after death” (Reiter). Researchers find in the autopsies that there is “a buildup of protein in the brain that has been associated with dementia in football players” (Epstein). Concussions are unlike any other traumatic brain injury. Rather, a “concussion lacks clearly defined signs or symptoms or diagnostic modalities such as routine brain imaging" (355). In 2005, Omalu, an NFL player for 17 years, committed suicide after 12 years of retirement from the impact sport. After two different autopsies, Omalu was confirmed to have the "tau" protein which is a sure indication of CTE. Prior to his suicide, Omalu was diagnosed with a major depressive disorder after multiple suicide attempts. The symptoms that could indicate one suffering from CTE include heavy depression, aggression, deterioration of a player's behavior and trouble maintaining their life outside the playing field.

Typically, symptoms show up in athletes in their mid to late twenties, yet cases of death from CTE have been found in high school players and college players. "Athletes playing competitive football over the course of high school engaged in contact sports are estimated to suffer upwards of 8,000 hits to the head" (McAllister). This number sounds alarming to any parent. Discussions about the age when adolescents should start football or other contact sports are becoming more common. largely being taken into consideration.

Virginia Tech's STAR system has developed into a widely respected ranking system for overall helmet safety based on several different helmet models. "Virginia Tech's current evaluation process (which it says will change beginning fall 2014) involves performing 120 impact tests on each helmet model at multiple locations and impact energies utilizing the STAR (Summation of Tests for the Analysis of Risk) Evaluation System, which it developed based on data collected from over 1.8-million head impacts experienced by football players over an eight-year period" (momsTEAM). After this vast amount of data is collected, analysis was done using trends and probabilities. After testing, a STAR rating is given where the the lower the number, "the better the helmet is believed by Virginia Tech to be in reducing the risk of concussion" (momsTEAM). Through this system, each helmet is also rated in "stars" from one to five. One star would result in a “not recommended” rating from Virginia Tech and a five star helmet would be the optimal equipment to wear. Virginia Tech just released results of their most recent testing, which included helmets such as the “Adams a2000, Rawlings Quantum, Riddell 360, Riddell Revolution, Riddell Revolution Speed, Riddell VSR4, Schutt Air Advantage, Schutt DNA Pro+, Xenith X1 and Xenith X2” (Castillo). The results put the Adams helmet at the very bottom with a one star rating, and put the Riddell 360 helmet at the top with a five star rating. “On average, the helmets reduced the risk of skull fracture by 60 to 70 percent compared to not wearing a helmet, and lowered the risk of brain tissue bruising by 70 to 80 percent” (Castillo). By no means does a five star rating mean that that specific helmet is guaranteed to prevent concussions.

For helmets that have five and four star ratings, which a majority of the Riddell helmets do, there are still many lawsuits and injuries occurring. Of these Riddell helmets, it is specifically the Revolution model that seems to be appearing in the news in relation to injury and legal action. A news report released in 2014 listed the helmets used by the local youth football teams and the corresponding STAR rating of their helmets. This is an effective way to make public the type of safety equipment children are using. Unfortunately, most traumas and repetitive impacts which cause concussions and brain diseases, happen in practices. This is where safety equipment *and* safety practices need to evolve to meet healthier standards.

The National Operating Committee on Standards for Athletic Equipment (NOCSAE) clearly defines standards for specifications for a football helmet and all of its components (chinstrap, padding, cage, etc.) to meet before it can be considered a new helmet. Similarly, there are other clearly defined standards for the specifications on recertifying a helmet.

Additionally, a tag with the text (or similar wording) is provided on each helmet stating: "If this product cracks or shows signs of stress it should be replaced. In any case we recommend replacement every two seasons at the varsity level and three seasons at the youth level" (NOCSAE). All of the information provided thus far is applicable to all football helmets. Although not every helmet size can be tested, "The most critical sizes are tested in the three or four most common shell sizes used by most equipment manufacturers. These sizes have the least amount of standoff distance between head and shell, and if these shell sizes meet the NOCSAE standard, it is reasonable to assume the other helmet sizes in that particular shell would also pass" (NOCSAE).

When the NOCSAE requires helmets to be reconditioned, it is important to understand how exactly Riddell tests their helmets for recertification and how they are reconditioned if they do not pass the test specifications. Riddell is the most popular and highest rated helmet used in

Image 1: Skull cap bladder insert prototype.

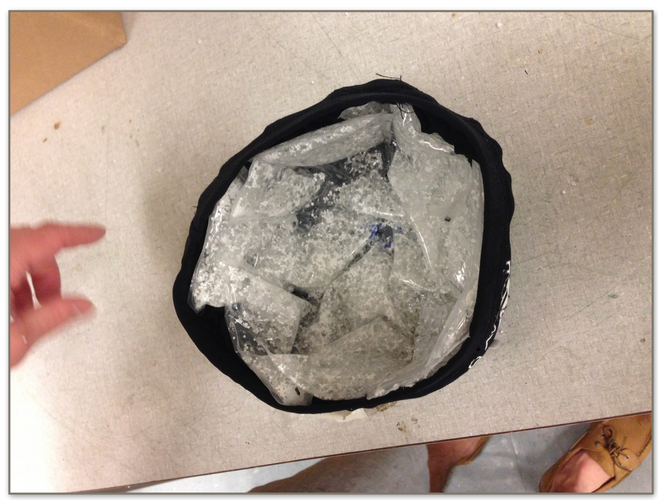


Image 2: Early prototype of Christopher's skull cap design.

any American football league today. Riddell not only manufactures helmets, they are "one of the few manufacturers who successfully expanded into the reconditioning business with its All-American Products division" (Mazzola). Riddell has such a good business model that they are one of the stronger athletic manufacturers that can vie in a very competitive reconditioning marketplace. Riddell seems does not publicly release their reconditioning process or what qualifies a helmet, yet other competitive reconditioning companies share promising input. A professional in the reconditioning industry at Solar System Athletics explains that "testing alone does not ensure the safety of the helmet. All it does is make sure that all the pieces are in the helmet" (Mazzola, Simchuck). Simchuck advises high school coaches to ask reconditioning companies "how many helmets over the year they have failed through rectification … good companies will tell you how many failed and will explain why" (43). It is also important that coaches go to the reconditioning plant, watch their equipment being tested and ask if the way they test meets NOCSAE standards (44).

Solution & Testing

Alternative Solutions

One solution could be Christopher Fuhrman's skull cap innovation. This concept is a skull cap that has a form of cushioning inside and would be worn underneath a player's helmet. This solution could apply to virtually any sport and could really change the economics of athletic protection. With a relatively inexpensive skull cap that could provide adequate added protection, players and schools who cannot afford to recondition or replace football helmets, could invest in this alternative solution. Thus far, Fuhrman has undergone research and development of such a cap. Recent testing has been conducted and has shown promise, however design changes and stability changes are being made.

Another solution is a quite simple one: teach kids from the beginning the proper techniques for impacting or tackling other players and modify practice and game rules (Daniel et. al). Scientists agree for the most part that serious brain conditions that occur in sports players (especially football) come from multiple, repetitive concussions. Therefore, modifying practices to eliminate harsh impacts can greatly reduce the number of impacts to the head a typical player receives (Daniel et. al). According to the study done by Ray W. Daniel, Steven Rowson, and Stefan M. Duma, a total of 748 impacts occurred during just one season distributed amongst seven youth players. Of these 748 impacts, there was an average of 107 impacts per player, per season and an average of over 6 impacts per practice and over 5 impacts per game. Therefore, it is easy to see that eliminating harsh impacts in practices reduces the total amount of impacts per season greatly. Adjusting the rules for practice is one very simple but impactful solution to the issue of football player concussions.

Jake Merrell of Xonano Foam, also poses another solution that could be enacted in real time. He has designed a system to go into football helmet pads that can read back shock data as the player is in the game. This information is collected by piezoelectric sensors that take a voltage and convert it into a shock value (BYU News). Once the shock value has been exceeded by the player, someone in charge of monitoring performance on the sidelines can notify a coach and remove the player from the field. “Merrell’s piezoelectric foam accounts for both force and acceleration to measure actual impact (BYU News).”

Statistical Testing

For data analysis purposes, this is a controlled experiment.

- Hypothesis
    - *Null hypothesis*: Youth football helmets show no difference in safety (quantified by G value) as compared to college football helmets.
    - *Alternative hypothesis*: Youth football helmets are much less safe (quantified by a higher G value) as compared to college football helmets.

- Variables
    - Controlled variables:
        - Helmet brand/style
        - Drop height
        - Drop location
        - Helmet level (youth versus college)
    - Dependent variables:
        - The shock values (in G's)
        - Deceleration time (in ms)
    - Independent variables:
        - There will be seven different locations on the helmet that it will be dropped on.

- Helmets for testing will be selected at random regardless of player's position on the field, which might cause some helmets to perform better than others.

- Data collection
  - Seven locations on the helmet will receive impact.
  - SaverXware software will collect results digitally from the accelerometer's read out.
  - Youth and college-level helmets will be the test subjects.

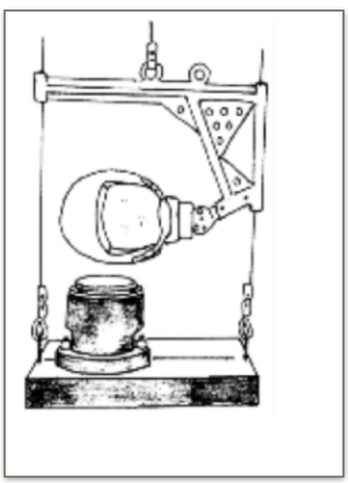


Figure 1: Side Impact Position

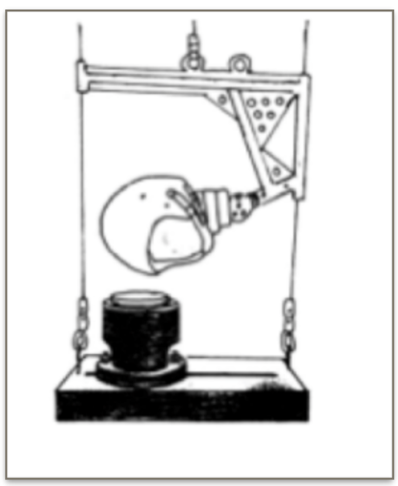


Figure 2: Boss (Front Left/Right) Impact Position

Figure 3: Front Impact Position

Testing Procedure

1. Setting up the Saver 9X30 accelerometer

a. Plug the accelerometer into the computer using the USB cord

b. Open the Saver X software on the computer

c. Choose "Load Setup" and choose the helmet drop set-up file that has a ".SXe" file extension

d. Once the .SXe database/setup file has been loaded, send this to the instrument by clicking "send set up to instrument."

e. A window will pop up that will provide options for when to begin the test. From the drop down menu, select "push button start." This will delay the accelerometer from collecting readings until the blue button on the Saver 9X30 has been pressed.

f. Finally, once the blue button has been pressed, a green blinking light should appear. At first, it will blink twice fast, after a minute or two, it will blink once slowly. Now the accelerometer is ready to collect data.

2. Preparing the helmets for testing

a. Using a piece of tape attached to each helmet, designate which helmets will be dropped and in what order. Typically, this is done by numbering the helmets 1, 2, 3, ... etc. This is because the data that will be read off of the computer will be displayed in order of the drops and it is important to keep track of which helmet belongs to which piece of data.

b. For the seven locations the helmets will each be dropped on, use a piece of tape to accurately mark these locations on each helmet. For this experiment, the front, top, back, front left, front right, left side, and right side were the locations used.

c. Next, make sure the headform is positioned so that the part of the helmet to be tested will impact the anvil directly. To do this, there are four hex bolts holding the headform still on the socket. These can be tightened and loosened to achieve the proper positioning.

d. Finally, helmets can be fitted onto the headform. Once they are snuggly attached, the apparatus is ready to undergo drop testing.

Figure 4: Helmet Impact Position

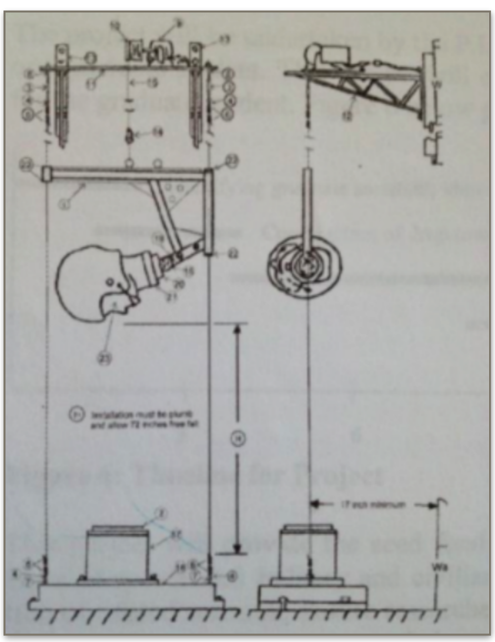
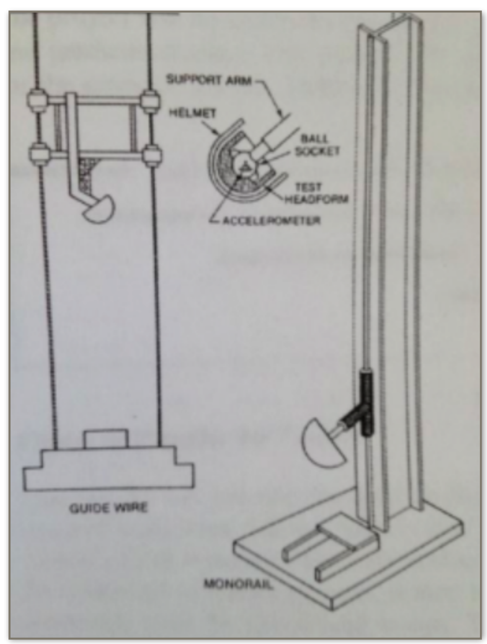


Figure 5: Testing Apparatus



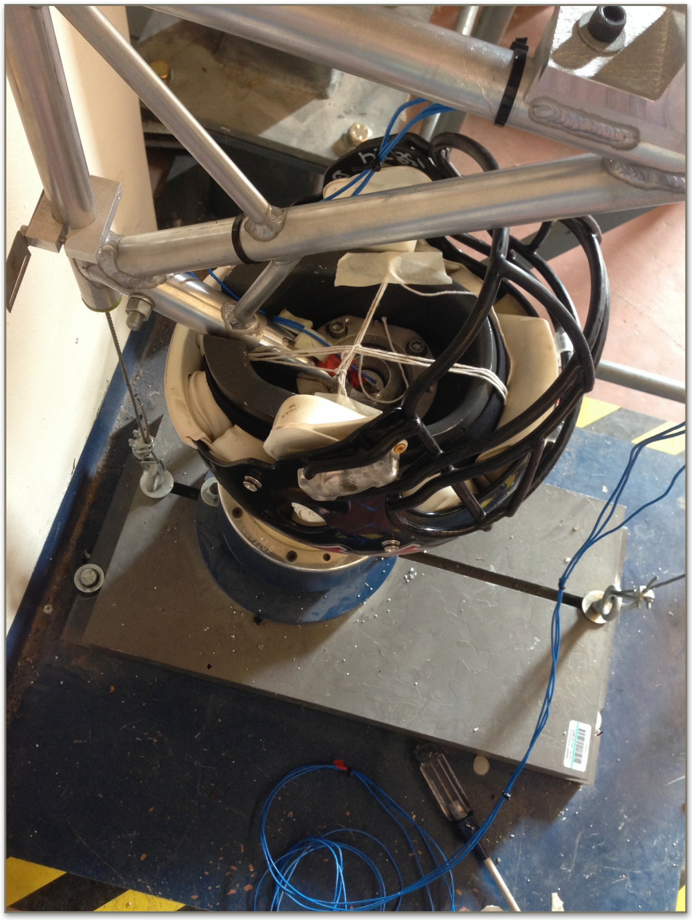


Image 3: Rear impact while helmet remains secured on the head form

3. Impact testing the helmets

a. Raise the helmet and headform apparatus into the clips at the top of the impact testing machine. These clips will hold the helmet at a constant height until it is dropped.

b. To drop the helmet, there is a black button on either side of the control box. Each button controls one side of the clip that is holding the helmet at the top of the machine. These black buttons need to be pressed simultaneously in order to drop the helmet successfully.

c. Once the helmet has been dropped, remove it from the headform and replace it with the next helmet to be tested. Repeat steps (a) and (b) as many times as needed.

d. After all helmets have been tested at the current impact position (front, top, etc.) plug the accelerometer back into the computer to read the collected data.

4. Reading Collected Data from the Accelerometer

a. Click "read back data" and save the file as the position where the helmet was tested (i.e. Top_Impact).

b. Click "direct view" and pick the file that was just saved in step (a).

c. If the database file (.SXe file) has not already been loaded, select "set event" and chose the database file.

d. Finally, choose "process event" and choose the saved file from step (a).

e. Now, to view the data collected, choose "analyze" and the data should appear. For helmet drops, shock is the value that is most important to look at. Thus, at the top of the analysis window, choose "view" and uncheck "vibration."

5. Repeating the process

a. To continue testing, revisit the previous steps and repeat as necessary to complete testing. Please note, the accelerometer needs to be set up (see "Setting up the Saver 9X30 accelerometer") each time the impact positioned is changed. This is to keep track of impacts in respect to the impact position.

Image 4: Helmet loaded into dropping mechanism

Image 5: Drop Impact Tester used for this study

Example of Testing Table: Table 1

Drop Location: ______________________________ **Helmet level:** (youth or college)____________

Helmet Number	Helmet condition, reconditioning date, notes, etc.	Deceleration (Gs)	Deceleration Time (ms)

Results/Discussion

Statistical Values and Other Terms Defined

Below are the definitions of these statistics terms for the purposes of this study.

- **Shock Value:** refers to the force of the mass multiplied by G
- **G:** a dimensionless value that measures deceleration as a multiple of gravity.
- **Mean:** the mathematical average shock value (in Gs) of the impact in that specific location on the helmet.
- **Standard Deviation:** how much variation from the sample mean there is; the lower this number is, the closer the value is to the sample mean.
- **SE Mean:** The standard deviation divided by the square root of the sample size. This measures the sample to sample variability of the mean.
- **Minimum:** within the drops in a specific location, this is the lowest shock value a helmet received.
- **Maximum:** within the drops in a specific location, this is the highest shock value a helmet received.
- **T-value:** this is a testing statistic that refers to a t-distribution and can be looked up on a chart; the bigger this number is, the smaller the p-value gets.
- **P-value:** this value is the probability that the observed results would have happened by fluke or coincidence; most times this value is compared to either 0.05 (5%) or 0.10 (10%), meaning that if the p-value is less than 0.05, the null hypothesis is rejected in favor of the alternative hypothesis.

Overall Statistics

After completing the physical impact testing on the youth helmets and then analyzing the results via statistical testing, the results were surprising. The mean for the entire helmet over all seven impact locations was 123.5 G with an average standard deviation of 14.86 (see Appendix for raw data for individual impact locations). The back of the helmet actually received the highest amount of shock of any part of the helmet at 149.93 G. This could possibly be explained in that most tackles that occur during football come from the side or the front. Thus, the back might not be quite as padded as other locations inside the helmet. However, this provides an area of improvement for these youth helmets because all parts of the helmet should be equally protected.

What came most as a surprise was that the college helmets, which are reconditioned annually, didn't necessarily perform differently than the youth helmets. The college helmets had an overall (throughout all seven locations) shock value of 129.00 G, with an average standard deviation of 20.07 G. This, of course, is much higher than the values associated with the youth football helmet testing, but not necessarily significant given the high variability (the square of the standard deviation) from helmet to helmet. The highest value for the college helmets was also given to the back of the helmet. The back of the helmet registered 166.00 G. The same argument can be made that all points of the helmet should be fully padded and protected, but what really seemed surprising is the extremely high shock value (almost 15 G higher than the maximum youth football helmet impact).

What is the most important point to note is that there is a large variation from helmet to helmet in both the youth and college level helmet categories. An analysis of variance was also conducted on the data and seems to show that neither brand, nor the age category showed any significant impact on the data. Thus, pointing towards there being no overall difference in the youth helmets versus the college helmets in terms of impact testing results. This is talked about in more detail below. The statistical data results are also listed below.

T-test and 95% Confidence Interval for Youth Helmets vs. College Helmets

- ***Top***

For this location, the difference in youth top and college top in terms of mean Gs, is -28.2. The p-value is 0.024, which means that at the 5% significance level, the null hypothesis (which says there is no difference in mean G value for youth versus college helmets) should be rejected. Thus, there is evidence supporting the alternative hypothesis (which says that there is a difference in youth versus college helmets in terms of mean G value). In this particular location, however, the confidence interval is (-51.7, -4.7). The negative values for both the upper and lower bound indicate that the youth helmets performed better (received lower G values) than the college helmets at this location.

- ***Front***

For this location, the difference in youth front and college front in terms of mean Gs, is -21.5. The p-value is 0.022, which means that at the 5% significance level, the null hypothesis (which says there is no difference in mean G value for youth versus college helmets) should be rejected. Thus, there is evidence supporting the alternative hypothesis (which says that there is a difference in youth versus college helmets in terms of mean G value). In this particular location, however, the confidence interval is (-39.13, -3.88). The negative values for both the upper and lower bound indicate that the youth helmets performed better (received lower G values) than the college helmets at this location.

- ***Back***

For this location, the difference in youth back and college back in terms of mean Gs, is 9.9. The p-value is 0.387, which means that at the 5% significance level, the null hypothesis (which says there is no difference in mean G value for youth versus college helmets) should not be rejected. Thus there is not evidence supporting the alternative hypothesis (which says that there is a difference in youth versus college helmets in terms of mean G value). In this particular location, however, the confidence interval is (-14.5, 34.2). The negative value for the lower bound and positive value for the upper bound means that the interval captures zero, which indicates that there is no significant difference between college and youth helmets in terms of impact testing performance at this location.

- ***Front Left***

For this location, the difference in youth front left and college front left in terms of mean Gs, is -15.81. The p-value is 0.121, which means that at the 5% significance level, the null hypothesis (which says there is no difference in mean G value for youth versus college helmets) should not be rejected. Thus there is not evidence supporting the alternative hypothesis (which says that there is a difference in youth versus college helmets in terms of mean G value). In this particular location, however, the confidence interval is (-36.61, 5.00). The negative value for the lower bound and positive value for the upper bound means that the interval captures zero, which indicates that there is no significant difference between college and youth helmets in terms of impact testing performance at this location.

- ***Front Right***

For this location, the difference in youth front right and college front right in terms of mean Gs, is -14.5. The p-value is 0.198, which means that at the 5% significance level, the null hypothesis (which says there is no difference in mean G value for youth versus college helmets) should not be rejected. Thus there is not evidence supporting the alternative hypothesis (which says that there is a difference in youth versus college helmets in terms of mean G value). In this particular location, however, the confidence interval is (-38.0, 9.1). The negative value for the lower bound and positive value for the upper bound means that the interval captures zero, which indicates that there is no significant difference between college and youth helmets in terms of impact testing performance at this location.

- ***Left Side***

For this location, the difference in youth left side and college left side in terms of mean Gs, is 13.9. The p-value is 0.234, which means that at the 5% significance level, the null hypothesis (which says there is no difference in mean G value for youth versus college helmets) should not be rejected. Thus there is not evidence supporting the alternative hypothesis (which says that there is a difference in youth versus college helmets in terms of mean G value). In this particular location, however, the confidence interval is (-10.5, 38.3). The negative value for the lower bound and positive value for the upper bound means that the interval captures zero, which indicates that there is no significant difference between college and youth helmets in terms of impact testing performance at this location.

- ***Right Side***

For this location, the difference in youth right side and college right side in terms of mean Gs, is 17.73. The p-value is 0.083, which means that at the 5% significance level, the null hypothesis (which says there is no difference in mean G value for youth versus college helmets) should not be rejected. Thus there is not evidence supporting the alternative hypothesis (which says that there is a difference in youth versus college helmets in terms of mean G value). In this particular location, however, the confidence interval is (-2.86, 38.33). The negative value for the lower bound and positive value for the upper bound means that the interval captures zero, which indicates that there is no significant difference between college and youth helmets in terms of impact testing performance at this location.

Conclusion/Observations

The overall purpose of this study was to look at the safety of youth football helmets and compare those results to how college football helmets performed under the same tests. The assumption was the youth helmets would perform worse than college football helmets, which are annually reconditioned. The question at the beginning of the study, therefore, was how much worse were the youth helmets going to perform? The surprise came when, in most cases, there was not a significant difference between the results in the college helmets and the youth helmets tested. While this wasn't true in every case, it seems to be the general result from the study. Of course, this was a small sample size and results could very well differ if a larger sample was used. However, in five out of the seven locations, the statistical analysis proved that there was no significant difference between the means of the two groups of helmets when split up by impact location.

In the end, it is obvious that the expected results were not seen. Although the results of this study point to there being no significant different between the means of the two groups of helmets, in the two cases where there was a significant difference, the youth helmets out-performed the college helmets in impact testing. Thus, it is clear that there are further opportunities for research and testing to find an answer of why exactly this occurred.

By no means do these outcomes deem either class of helmets safer than one or the other, nor do they deem either class simply "safe." The summation of evidence outlined by this report clearly underlines the need for not only an improved helmet design, but also an overall reformatting of how football (and sports in general) are played, especially at a youth level.

Whether the helmet redesign come from Christopher Furhman or Jake Merrell, it is obvious that helmets give the player a false sense of security that is amplified by the younger demographic, who are already wired to take their own safety for granted in the name of fun. The false sense is driving players, and coaches, to practice harder, and play the game harder than is necessary. The average human head cannot withstand continuous impacts of such a high degree without consequence. And, unfortunately, those consequences are all too prevalent in the news today with concussions being in such a high relation to recent suicides of former NFL players. It is easy to let these big name athletes take precedent over the children imitating their favorite players during games or practices, which begins head trauma at an early age. If youth helmets and college helmets really are on par with their ability to withstand (or not withstand) impact, then there needs to be a big change in the sport and its equipment to ensure safety for a much larger group than is already recognized.

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Appendix

Gantt Chart

Date	Development	Contributors
1/12/2014	Begin research on head trauma and related diseases	Nicole Hermann
1/13/2014	Recieve and set up Saver 9X30 from recalibration	Nicole Hermann
1/24/2014	Meet with Christopher Furhman to discuss football accidents and recent innovations in protection	Nicole Hermann, Christopher Furhman and Tom Furhman
1/25/2014	Begin and complete testing for youth football helmets	Nicole Hermann, Christopher Furhman and Tom Furhman
1/27/2014	Meet with Jay Singh (research advisor) to discuss project direction and youth testing results	Nicole Hermann, Jay Singh
1/27/2014	Meet with Soma Roy (statistician) to discuss project direction and possibilities for analysis of youth football testing results	Nicole Hermann, Soma Roy
1/29/2014	Contact local schools for additional helmets to test -- limited response, no cooperation	Nicole Hermann
2/5/2014	Meet with Soma Roy to further discuss analysis possibilities -- determined a larger sample size is needed	Nicole Hermann, Soma Roy
2/5/2014	Contact college football equipment manager Steve Kracher to secure college level helmets -- projection direction solidified to show differences between youth and college football helmets in relation to reconditioning	Nicole Hermann, Sally Yingst, Steve Kracher
2/6/2014	Recieve college helmets for testing	Nicole Hermann, Sally Yingst
2/8/2014	Begin and complete testing for college football helmets	Nicole Hermann, Sally Yingst
2/12/2014	Consult Dr. Roy for final recommendations on statistical analysis	Nicole Hermann, Soma Roy
2/16/2014	Conduct statistical analysis on data to obtain conclusions on youth football helmet safety	Nicole Hermann
3/10/2014	Final consultation with Dr. Roy in regards to conclusions and analysis of data	Nicole Hermann, Soma Roy

Statistical Analysis Used

Following are the results of statistical testing. Both descriptive and 2-sample t tests have been run on the data obtained from testing. Please note that all data points are presented in G's. Accompanying each t-test is a 95% confidence interval comparing youth and college helmets in each impact location based on the criteria:

- Ho: No difference in youth helmet G level and college helmet G level
- Ha: Youth helmets show different G level than college helmets

Descriptive Statistics: Youth Helmets

Variable	Mean	SE Mean	StDev	Minimum	Maximum
Youth Top	124.14	5.10	12.49	108.00	139.69
Youth Front	98.63	4.00	9.81	84.58	113.29
Youth Back	138.59	6.88	16.84	107.19	149.93
Youth Front Left	111.65	5.27	12.91	96.05	131.46
Youth Front Right	116.23	5.30	12.99	93.86	130.52
Youth Left Side	139.24	8.45	20.71	104.13	163.26
Youth Right Side	136.03	7.46	18.27	100.67	148.69

Descriptive Statistics: College Helmets

Variable	Mean	SE Mean	StDev	Minimum	Maximum
College Top	152.32	9.05	23.95	115.58	173.68
College Front	120.13	6.69	17.69	95.03	152.24
College Back	128.71	8.49	22.48	106.16	166.00

College Front Left	127.46	7.71	20.40	93.06	162.32
College Front Right	130.69	8.97	23.73	99.26	165.04
College Left Side	125.36	6.97	18.43	100.24	162.04
College Right Side	118.30	5.22	13.81	98.11	135.41

Two-Sample T-Test and CI: Youth Top, College Top

	N	Mean	StDev	SE Mean
Youth Top	6	124.1	12.5	5.1
College Top	7	152.3	23.9	9.1

Difference = mu (Youth Top) - mu (College Top)

Estimate for difference: -28.2

95% CI for difference: (-51.7, -4.7)

T-Test of difference = 0 (vs not =): T-Value = -2.71 P-Value = 0.024 DF = 9

Two-Sample T-Test and CI: Youth Front, College Front

	N	Mean	StDev	SE Mean
Youth Front	6	98.63	9.81	4.0
College Front	7	120.1	17.7	6.7

Difference = mu (Youth Front) - mu (College Front)

Estimate for difference: -21.51

95% CI for difference: (-39.13, -3.88)

T-Test of difference = 0 (vs not =): T-Value = -2.76 P-Value = 0.022 DF = 9

Two-Sample T-Test and CI: Youth Back, College Back

	N	Mean	StDev	SE Mean
Youth Back	6	138.6	16.8	6.9
College Back	7	128.7	22.5	8.5

Difference = mu (Youth Back) - mu (College Back)

Estimate for difference: 9.9

95% CI for difference: (-14.5, 34.2)

T-Test of difference = 0 (vs not =): T-Value = 0.90 P-Value = 0.387 DF = 10

Two-Sample T-Test and CI: Youth Front Left, College Front Left

	N	Mean	StDev	SE Mean
Youth Front Left	6	111.6	12.9	5.3
College Front Left	7	127.5	20.4	7.7

Difference = mu (Youth Front Left) - mu (College Front Left)

Estimate for difference: -15.81

95% CI for difference: (-36.61, 5.00)

T-Test of difference = 0 (vs not =): T-Value = -1.69 P-Value = 0.121 DF = 10

Two-Sample T-Test and CI: Youth Front Right, College Front Right

	N	Mean	StDev	SE Mean
Youth Front Right	6	116.2	13.0	5.3
College Front Right	7	130.7	23.7	9.0

Difference = mu (Youth Front Right) - mu (College Front Right)

Estimate for difference: -14.5

95% CI for difference: (-38.0, 9.1)

T-Test of difference = 0 (vs not =): T-Value = -1.39 P-Value = 0.198 DF = 9

Two-Sample T-Test and CI: Youth Left Side, College Left Side

	N	Mean	StDev	SE Mean
Youth Left Side	6	139.2	20.7	8.5
College Left Side	7	125.4	18.4	7.0

Difference = mu (Youth Left Side) - mu (College Left Side)

Estimate for difference: 13.9

95% CI for difference: (-10.5, 38.3)

T-Test of difference = 0 (vs not =): T-Value = 1.27 P-Value = 0.234 DF = 10

Two-Sample T-Test and CI: Youth Right Side, College Right Side

	N	Mean	StDev	SE Mean
Youth Right Side	6	136.0	18.3	7.5
College Right Side	7	118.3	13.8	5.2

Difference = mu (Youth Right Side) - mu (College Right Side)

Estimate for difference: 17.73

95% CI for difference: (-2.86, 38.33)

T-Test of difference = 0 (vs not =): T-Value = 1.95 P-Value = 0.083 DF = 9

Due to multiple hypothesis tests, each at 5% significance level, it should be noted that there is a chance of false rejection of the null hypothesis. To account for this, one possible solution would be to divide the significance level by the number of testings, in this case the 5% significance level would be divided by the seven testing locations on the helmet.

Raw Data

Youth Data Collected: Table 3

Location: Top		
Helmet Number, Condition	**Shock Level (in Gs)**	**Deceleration Time/ Impact Time (in ms)**
1 – Reconditioned	139.69	13
2 – Reconditioned	128.26	14
3 – Reconditioned	112.54	14
4 – Reconditioned	121.34	15
5 – Reconditioned	135.03	13
6 – Brand New	108	15
Location: Front		
Helmet Number, Condition	**Shock Level (in Gs)**	**Deceleration Time/ Impact Time (in ms)**
1 – Reconditioned	84.58	19
2 – Reconditioned	102.47	13
3 – Reconditioned	91.53	15
4 – Reconditioned	113.29	15
5 – Reconditioned	100.03	16
6 – Brand New	99.87	15
Location: Back		
Helmet Number, Condition	**Shock Level (in Gs)**	**Deceleration Time/ Impact Time (in ms)**
1 – Reconditioned	149.3	12
2 – Reconditioned	149.93	14
3 – Reconditioned	132.17	14
4 – Reconditioned	149.91	13
5 – Reconditioned	143.05	15

6 – Brand New	107.19	15
Location: Front Left		
Helmet Number, Condition	**Shock Level (in Gs)**	**Deceleration Time/ Impact Time (in ms)**
1 – Reconditioned	117.14	15
2 – Reconditioned	98.92	15
3 – Reconditioned	113.45	14
4 – Reconditioned	131.46	13
5 – Reconditioned	112.88	14
6 – Brand New	96.05	13
Location: Front Right		
Helmet Number, Condition	**Shock Level (in Gs)**	**Deceleration Time/ Impact Time (in ms)**
1 – Reconditioned	112.29	14
2 – Reconditioned	118.48	15
3 – Reconditioned	130.52	12
4 – Reconditioned	127.06	12
5 – Reconditioned	115.14	16
6 – Brand New	93.86	14
Location: Left Side		
Helmet Number, Condition	**Shock Level (in Gs)**	**Deceleration Time/ Impact Time (in ms)**
1 – Reconditioned	163.26	12
2 – Reconditioned	143.85	13
3 – Reconditioned	127.31	13
4 – Reconditioned	149.51	14
5 – Reconditioned	147.35	13
6 – Brand New	104.13	15
Location: Right Side		

Helmet Number, Condition	**Shock Level (in Gs)**	**Deceleration Time/ Impact Time (in ms)**
1 – Reconditioned	148.69	13
2 – Reconditioned	131.91	13
3 – Reconditioned	144.81	13
4 – Reconditioned	145.64	13
5 – Reconditioned	144.46	13
6 – Brand New	100.67	16

*All youth helmets tested are Riddell brand.

College Data Collected: Table 4

Location: Top		
Helmet Number, Condition, Brand	**Shock Level (in Gs)**	**Deceleration Time/Impact Time (in ms)**
1 - Reconditioned, Schutt	115.58	15
2 - Reconditioned, Schutt	130.92	14
3 - Reconditioned, Schutt	173.68	13
4 - Brand new, Riddell	137.37	9
5 - Reconditioned, Riddell	172.67	12
6 - Reconditioned, Riddell	163.19	11
7 - Reconditioned, Riddell	172.85	8
Location: Front		
Helmet Number, Condition, Brand	**Shock Level (in Gs)**	**Deceleration Time/Impact Time (in ms)**
1 - Reconditioned, Schutt	109.58	14
2 - Reconditioned, Schutt	127.86	14
3 - Reconditioned, Schutt	117.74	13
4 - Brand new, Riddell	95.03	14
5 - Reconditioned, Riddell	152.24	15
6 - Reconditioned, Riddell	123.6	14
7 - Reconditioned, Riddell	114.89	11
Location: Back		
Helmet Number, Condition, Brand	**Shock Level (in Gs)**	**Deceleration Time/Impact Time (in ms)**
1 - Reconditioned, Schutt	123.54	16
2 - Reconditioned, Schutt	111.44	15
3 - Reconditioned, Schutt	106.16	13
4 - Brand new, Riddell	109.11	11

5 - Reconditioned, Riddell	147.35	9
6 - Reconditioned, Riddell	137.38	14
7 - Reconditioned, Riddell	166	12
Location: Front Left		
Helmet Number, Condition, Brand	**Shock Level (in Gs)**	**Deceleration Time/Impact Time (in ms)**
1 - Reconditioned, Schutt	93.06	15
2 - Reconditioned, Schutt	129.44	14
3 - Reconditioned, Schutt	130.6	14
4 - Brand new, Riddell	129.17	13
5 - Reconditioned, Riddell	162.32	11
6 - Reconditioned, Riddell	118.56	13
7 - Reconditioned, Riddell	129.04	11
Location: Front Right		
Helmet Number, Condition, Brand	**Shock Level (in Gs)**	**Deceleration Time/Impact Time (in ms)**
1 - Reconditioned, Schutt	100.91	15
2 - Reconditioned, Schutt	99.26	16
3 - Reconditioned, Schutt	132.67	13
4 - Brand new, Riddell	132.85	12
5 - Reconditioned, Riddell	165.04	10
6 - Reconditioned, Riddell	136.75	12
7 - Reconditioned, Riddell	147.36	11
Location: Left Side		
Helmet Number, Condition, Brand	**Shock Level (in Gs)**	**Deceleration Time/Impact Time (in ms)**
1 - Reconditioned, Schutt	125.4	14
2 - Reconditioned, Schutt	118.23	15
3 - Reconditioned, Schutt	100.24	16

4 - Brand new, Riddell	122.63	15
5 - Reconditioned, Riddell	123.7	15
6 - Reconditioned, Riddell	125.29	15
7 - Reconditioned, Riddell	162.04	13
Location: Front Right		
Helmet Number, Condition, Brand	**Shock Level (in Gs)**	**Deceleration Time/Impact Time (in ms)**
1 - Reconditioned, Schutt	118.59	17
2 - Reconditioned, Schutt	131.01	15
3 - Reconditioned, Schutt	108.45	16
4 - Brand new, Riddell	98.11	16
5 - Reconditioned, Riddell	135.41	14
6 - Reconditioned, Riddell	108.61	15
7 - Reconditioned, Riddell	127.89	15